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Effects of work experience and exertion height on static lifting strengths and lift strategies of experienced and novice female participants

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A B S T R A C T

In this study, 46 female experienced workers and inexperienced novices (23 each) were recruited to determine their maximum lifting strength at 15 exertion heights between 10 and 150 cm from the floor. The results revealed that the experienced workers' strengths at all 15 heights exhibited relatively little fluctuation, and were approximately 50–70 N lower than those of novices when heights were ≤50 cm. No differences in strengths were observed at 60–150 cm between the groups. The experienced workers tended to adopt a consistently deep squat at lower heights (≤50 cm) and a more erect posture with stiffened arms at higher heights (≥70 cm), resulting in lower L4/L5 disc compression forces and shoulder moments than in novices, respectively. In contrast to the lifting techniques adopted by experienced workers to effectively avoid overloading, the findings suggest that novice female workers who lack experience should be cautious and trained for performing lifting tasks.

Relevance to industry: This study demonstrated that a discrepancy exists in lifting strengths between experienced and inexperienced female handlers at various heights. Findings from this study offers a reference for lifting task design and effective posture training on lifting, regarding the weighting of various shelves.

1. Introduction

Manual handling remains prevalent in Taiwan, and over 500,000 workers are employed in jobs related to warehousing (CEPD, 2011). Most tasks in warehouses, distribution centers, and various retail establishments involve manual materials handling and strength exertion at various heights of lift. These tasks typically involve submaximal weights; in other words, the weights handled are light to moderate and therefore do not require only male employees. A recent study of Taiwanese warehouse workers revealed that the lower back, shoulders, and arms were regions of bodily discomfort for both male and female workers, particularly for novice workers (Chen, 2008). This might have resulted from the warehousing tasks, which were highly repetitive but diverse in lifting heights, that these workers were asked to perform.

One factor affecting lifting strength is the exertion height; in other words, the height at which the lift is initiated (Yates et al., 1980; Mital et al., 1993; Lee, 2004; Chen et al., 2011). This is particularly true in service warehouse stores, which economize and maximize storage space. Lifting strength capacity most likely changes with height and thus placing a person at higher percentages of their maximum in some locations than others (Yates et al., 1980). The closer they are to their maximum, the greater their potential risk for injury (Mital et al., 1993). Investigations on lifting strength have typically been confined to specific height levels (e.g., floor, knuckle, and shoulder); however, this is not applicable to warehousing tasks. Height of lifting also influences posture, which, in turns, affects internal loads on potentially vulnerable tissues (Chen, 2000; Plamondon et al., 2012). Therefore, it is critical to understand the effect of height on lifting capacity and the corresponding body loads.

Much of the literature has reported that the handling techniques of highly skilled workers differ substantially from those of novices (Authier et al., 1996; Gagnon et al., 1996). Field studies have also revealed that workers use methods other than those traditionally recommended (Kuorinka et al., 1994; Baril-Gingras and Lortie, 1995; Authier et al., 1996). However, certain researchers have determined that experienced workers possess advantages; for a given task, experienced workers generally employ lower biomechanical spinal loads (Marras et al., 2006), fewer back-muscle

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activations (Keir and MacDonell, 2004), a narrower lumbar-spine range of motion (Hodder et al., 2010), higher subjective discomfort thresholds (Parakkat et al., 2007) and psychophysically accepted lifting weights (Mital, 1987), and a greater knee flexion during ground-level task (Plamondon et al., 2010, 2012) than novices. Conversely, Mital and Manivasagan (1983) indicated that task variables similarly influenced the maximum lifting capacities of experienced workers and college students, and controversy in this regard might be attributable to the distinct experimental settings adopted by these studies. Warehouses in Taiwan have high employee turnover rates, and recruit new full-time and part-time workers weekly (Chen, 2008). These inexperienced novice workers require more attentiveness to avoid injury resulting from daily tasks.

Recently, Chen et al. (2011) systemically assessed the lifting strength of male experienced workers and novices at full-range heights, and observed that the average strength lifted upward by novices was 4.57–7.61 kg lower than that of experienced workers when lifting at 100–120 cm heights. The workers' upward strengths, contrary to expectations, remained nearly unchanged throughout all 15 full-range heights. In that study, the postures adopted by the workers were also highly differentiated from that of the novices when performing near-floor positions, but their strengths were equivalent. Experienced workers tended to adopt a safer (i.e., more flexed knees) and more skillful technique than novices did to generate force, which might result in lower spinal loads during lifting. However in that study, only male experienced workers and inexperienced university students were compared.

Previous studies have demonstrated that the inherent difference in muscular characteristics between sexes (Xiao et al., 2005; Agrawal et al., 2009). Garg and Ayoub (1980) noted that the maximum lifting capacity of women was 60–70% that of men, and an earlier study by Murrel (1971) also suggested that women were able to exert approximately two-thirds the force of men. However, the ratio of isometric strength between Chinese men and women was nearly 50% (Xiao et al., 2005). Miller et al. (1993) observed that sex differences in muscle strength were primarily confined to muscles in the upper extremities, particularly the shoulders. Hooftman et al. (2009) indicated that even if men and women perform the same tasks, they do not perform these tasks in the same manner, which might also lead to differences in exposure. This can be attributed to a poorer ergonomic fit of the workplace to women than to men, or because men and women choose to perform the same task using distinct strategies. Lifting tasks distributed to male and female workers in supermarkets were observed to be identical regarding shelf heights and load weights. This might imply a higher risk for women than for men, because these tasks place the women at a disadvantage compared with men when lifting.

We therefore examined the effect of height on lifting capacity and the corresponding body loads for experienced and inexperienced female participants recruited from a large supermarket and a university, respectively. We hypothesized that experienced female participants' strengths and lifting strategies at 15 lifting heights would differ from inexperienced female participants' because of the daily workplace practices where the experienced group had worked. We also examined whether the results regarding the effects of these tasks on men were also applicable to women.

2. Methods

2.1. Participants

Forty-six experienced female workers and novice participants (23 of each), with no history of musculoskeletal disorders, volunteered for this study, and received an hourly wage for completing all of the test conditions. Twenty-three workers with a minimum of 2-years of experience were selected as experienced participants. They were selected from a large supermarket, and their duties consisted primarily of varied shelf-replenishing tasks. Another 23 novice participants (with no manual material-handling experience) were recruited from among university students, based on previous studies (Mital, 1987; Marras et al., 2006; Parakkat et al., 2007). Informed consent was obtained from all participants in accordance with the regulations. The Ethics Committee of Chang Gung Memorial Hospital of Taiwan approved this study. The mean (standard deviation; SD) age, stature, and body mass were 28.6 (6.4) years, 158.9 (5.3) cm, and 58.3 (10.2) kg for the experienced group, and 22.3 (3.2) years, 160.2 (4.1) cm, and 51.3 (6.5) kg for the inexperienced group, respectively. Detailed information, anthropometric data, and isometric muscular strengths for the 46 participants are listed in Table 1. The isometric strength measurement procedure was based on the studies of Ayoub et al. (1978) and Mital (1987).

2.2. Experimental apparatus

Lifting strengths were measured using the Static-Lifting Strength Tester (SLST), as shown in Fig. 1. The SLST, with incremental height settings for measuring strengths, consists of a standing platform, a steel frame with 15 positioning holes (ranging from 10 to 150 cm in increments of 10 cm), a sliding height stopper along the frame, and a 55-cm handle bar (diameter: 3.5 cm) attached to the stopper. Force applied vertically to the handle bar was measured by a load cell connected to the bar that was firmly attached to the stopper; the strength signal (40 Hz) was then transferred to an A-D converter and a digital readout unit (Jackson Strength Evaluation System, JSES Model 32628, USA). The A-D converter was calibrated prior to the strength testing against known weights.

2.3. Body posture recording and biomechanical analysis

The testing postures of randomly sampled participants (12 workers and 12 novices) were videotaped in this study. Six adhesive reflective markers were attached to the right side of their ulna

Table 1
Participant data for the experienced workers and novices (23 in each group).

Variables	Experienced workers		Novices	
	Mean	S.D.	Mean	S.D.
Age (years)*	28.6	6.4	22.3	3.2
Stature (cm)	158.9	5.3	160.2	4.1
Body mass (kg)*	58.3	10.2	51.3	6.5
Acromial height (cm)	127.8	5.03	128.0	4.88
Elbow height (cm)	95.5	3.81	96.9	2.63
Knuckle height (cm)	68.9	4.62	69.4	5.03
Hip height (cm)	81.7	6.30	83.0	6.15
Knee height (cm)	42.1	3.33	43.6	2.32
Hand length (cm)	14.9	0.64	14.9	0.67
Hand width (cm)	7.1	0.5	7.0	0.4
Isometric strengths (N)[a]				
Composite strength	599.8	132.3	611.5	138.2
Back strength	497.8	128.4	521.4	136.2
Shoulder strength	282.2	68.6	267.5	80.4
Arm strength	218.5	51.9	231.3	49.0

*Significantly different at $p < .05$.
[a] Testing procedure was based on the studies of Ayoub et al. (1978) and Mital (1987).